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# **Senior Review 2009 and the Mission Extension for the Earth Science operating missions Technical and Cost (T&C) Review**

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# Outline

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# Purpose of this Presentation

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Brief overview of the Principles, Process, and Results of the Technical and Cost (T&C) Review



# Introduction

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The NASA Earth Science Division (ESD) of the Science Mission Directorate (SMD) is supporting 13 Earth observing missions that are, or soon will be, operating beyond their prime mission lifetimes. Each of these missions has made unique contributions to NASA research objectives, and in many cases mission extensions have great potential for advancing the ESD science goals. Additionally, data from several of these *research* missions are being used routinely by other U.S. agencies in support of national goals for Earth system prediction and monitoring. Extended operations and associated data production activities require a significant fraction of the ESD annual budget. NASA and the ESD thus periodically evaluate the allocation of mission operation and data analysis funds with the aim of maximizing the missions' contributions to NASA's and the nation's goals. This periodic NASA evaluation process for missions in extended operations is known as the “**Senior Review**.”

The 2009 ESD Senior Review will assess the merit and **performance** of these thirteen missions: ACRIMSAT, Aqua, Aura, CALIPSO, CloudSat, EO-1, GRACE, ICESat, Jason-1, QuikSCAT, SORCE, Terra and TRMM. **Performance factors** are to include scientific productivity, contribution to national objectives, **technical status and budget efficiency**.

The objectives of the ESD Senior Review are to (1) identify those missions beyond their prime mission lifetime whose continued operation contributes cost-effectively to both NASA's goals



## Introduction (continued)

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and the nation's operational needs (**expected to be the overwhelming majority** of on-orbit missions); and (2) identify **appropriate funding levels** for those missions determined worthy for extension.

This year, the Senior Review 2009 and the Mission Extension for the Earth Science operating missions Review will comprise of two panels; the Senior Review Science Panel and the Core Mission Review Panel (CoMRP). The CoMRP is further divided into two subpanels; the National Needs subpanel, and the **Technical & Cost (T&C) subpanel**.

The Senior Review Science Panel, which also reviews the Science Merit, will be the primary independent analysis group. They have the sole responsibility to evaluate the scientific merit of the NASA mission based on the applicability of the mission's science to NASA Earth science strategic plans and objectives and **will consider the results from the CoMRP on their final review findings and ratings**.

The CoMRP will **assess the health and viability of the operating satellites, the proposed mission operations and data analysis costs and approaches**, and the utility and applicability of the mission's data products to satisfy national operational objectives of non-NASA agencies.



## Introduction (continued)

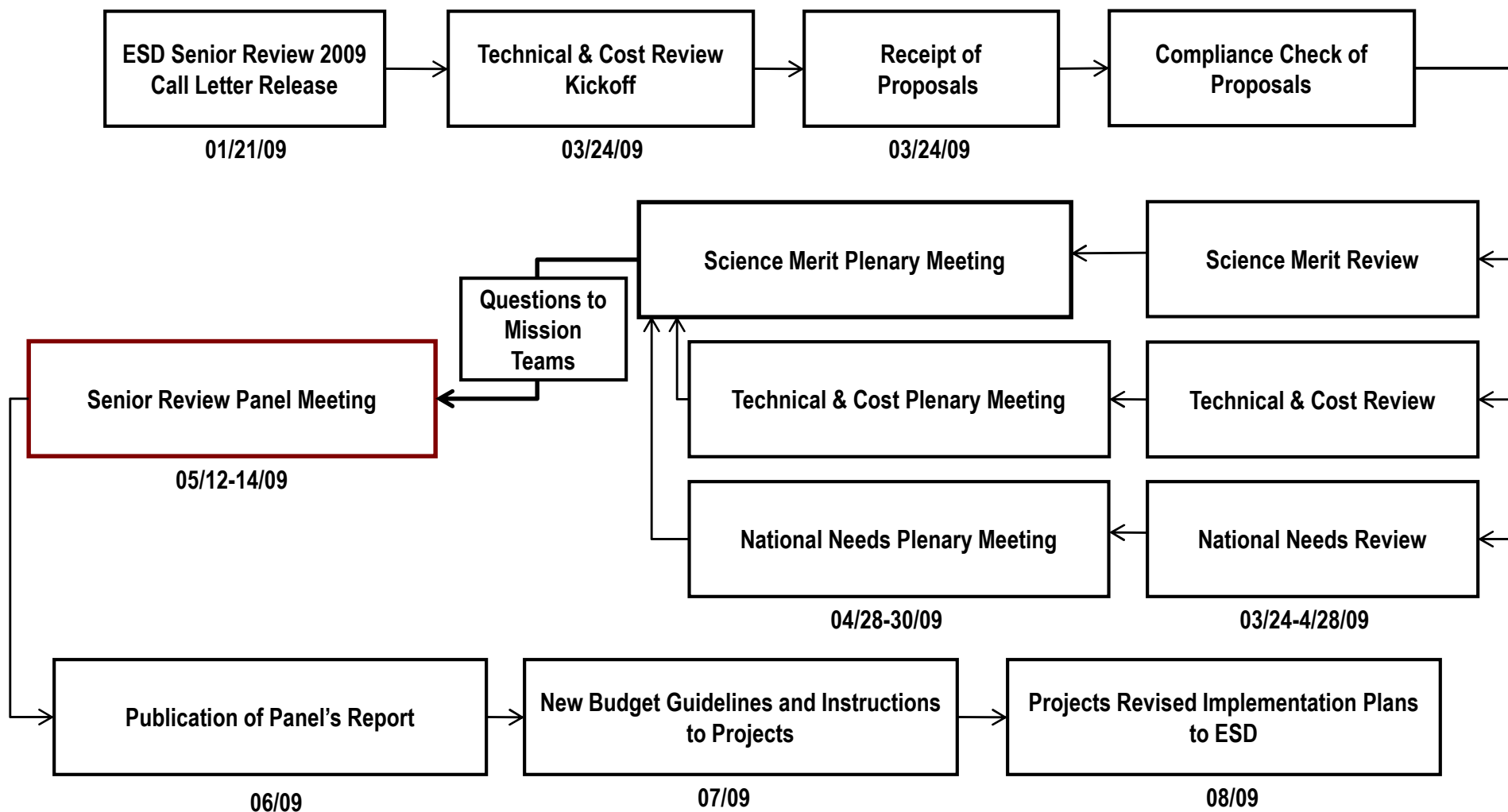
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The National Needs Subpanel, drawn primarily from other federal agencies and users of NASA research data for applied and operational purposes.

The Technical and Cost (T&C) Subpanel is drawn from technical experts in and outside NASA. ESD has requested the NASA Science Support Office (SSO) to perform a review that parallels the Technical, Management, and Cost (TMC) evaluations that the SSO performs on Pre-Phase A mission concepts. Since the missions will be proposing extensions on the Operations and Sustainment phase (extended Phase E), the review will emphasize the hardware status and performance and reliability projections, mission operations plans, the planned generation and delivery of the core data products, and the proposed cost realism. The management approach will be examined however it will not be evaluated in detail. Thus this part of the review will be referred to as the Technical and Cost (T&C) review of the ESD Senior Review.



# Review Flow





# Review Criteria and Selection Factors

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- Review Criteria for ESD Senior Review 2009
  - **Scientific Merit** of the proposed mission extension
  - **National Need** of the proposed mission extension
  - **Technical and Cost feasibility, including cost risk** of the proposed mission extension
- Selection factors
  - Total NASA ESD cost
  - A variety of programmatic factors





## Review Criteria Details

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### **Technical and Cost Feasibility, including Cost Risk, of the proposed mission extension**

- Each mission extension will be reviewed in detail for the feasibility of mission implementation as reflected in the perceived risk of accomplishing the extended mission within proposed resources. The Technical and Cost (T&C) Review will assess the factors as described below.

The proposal's performance and reliability projections for the satellite and instrument(s), the mission operations implementation plan, the planned generation and delivery of the core data products, and the likelihood of accomplishment within the proposed cost will be reviewed. The evaluation will consider factors including the status of consumables and predicted utilization; spacecraft and instrument status, performance degradation, and failure risk; mission operations approach for the effective and safe management of an aging satellite; and mission and data management. Strategies to preserve the health of the hardware, to mitigate performance degradation and failures, to manage on-orbit consumables, and to ensure the continued performance and reliability of the ground systems will be assessed. The adequacy and robustness of the cost plan will also be a factor in this evaluation. These factors will be evaluated for FY2010 - FY2011 and FY2012 - FY2013 mission extensions. The evaluation will result in narrative text as well as a risk rating for the feasibility of the extended mission implementation.



# Review

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## **T&C Review Principles**

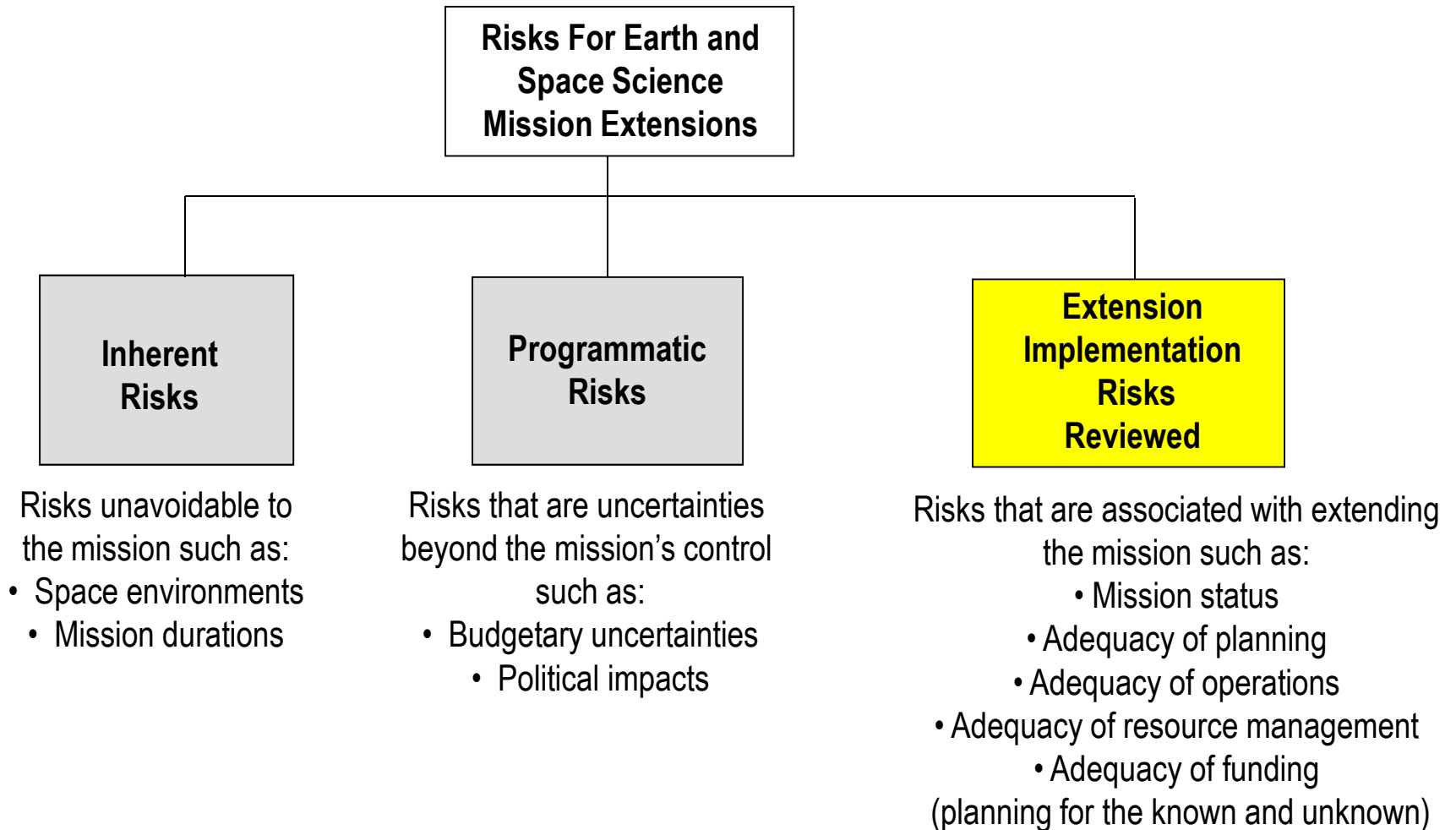
- Basic Assumption: The mission will be extended unless significant weaknesses are evident.  
Proposer is the expert on his/her proposal.
  - Proposer's Task is to provide evidence that the Mission Extension is Low Risk.
  - Review Panel Task is to try to validate proposer's assertion of Low Risk.
  - The proposed mission will be extended unless is not technically feasible. The Proposer is given the benefit of the doubt.
  - The cost is analyzed to determine whether is appropriate.
- All Proposals are reviewed to identical standards. They receive same evaluation treatment in all areas and are not compared to other proposals.
- The Review Panel is made up of reviewers that are experts in the areas that they review.
- Investigations are reviewed using only the Review Factors that apply to the specific mission.
- Cost Risk is reviewed against the proposed cost and the "in-guide" cost.
- The Review Panel develops findings for each proposal that reflect the general agreement of the entire panel.
  - Findings: As expected (no finding), above expectations (strengths), below expectations (weaknesses).



# Review

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## T&C Risk: What is reviewed.





# Review

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## T&C Risk Rating Definitions

- The T&C Review is to determine, for each proposed mission extension, the level of risk of implementing the mission extension as proposed and within proposed cost.
- T&C Risk Ratings: **Low Risk, Medium Risk, and High Risk**
  - **Low Risk:** No problems exist that cannot be normally overcome with the resources proposed. “Envelope adequate”.
  - **Medium Risk:** Problems exist, but are not sufficiently severe such that they cannot be overcome with good management and engineering. “Envelope tight”.
  - **High Risk:** Major Problems exist and proposed resources are insufficient to overcome the problems. “Does not fit within the Envelope”.
- **Envelope:** Resources available to handle known and unknown problems that may arise. Resources includes funding; status, reserves, and margins on physical resources such as power and propellant; fallback plans; and personnel.



# Review

## T&C Risk Envelope Concept

**Envelope:** Resources available to handle known and unknown problems that may arise. Resources includes funding; status, reserves, and margins on physical resources such as power and propellant; fallback plans; and personnel.

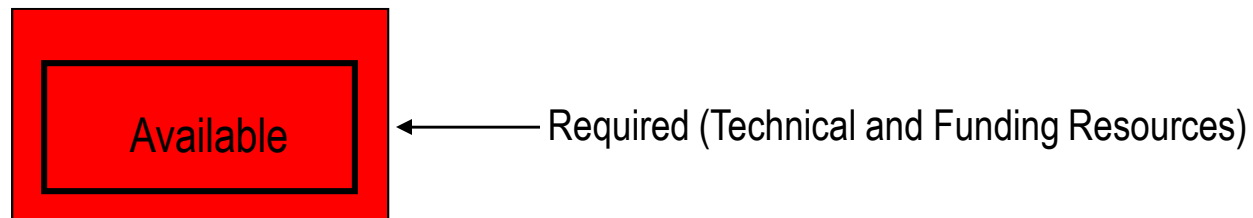
**Low Risk:** Required resources fit well within available resources.



**Medium Risk:** Required resources just barely inside available resources. Tight, but likely



**High Risk:** Required resources DO NOT fit inside available resources. Expect mission to fail





# Review

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## T&C Review Factors and Sub-Factors

The degree to which the proposal addresses the following factors directly relates to the Risk Rating.

- **Instrumentation**

- Status
- Projected lifetime
- Instrument Resource Management
- Redundancies
- Environment Concerns

- **Mission Design & Operations**

- Mission Operations
- Ground Facilities – New/Existing
- Telecom

- **Spacecraft/Flight Systems**

- Status - health and consumables
- Margins
- Spacecraft Resource Management
- Mission Assurance

- **Management and Schedule**

- Project-Level Schedule

- **Cost**

- Basis of Estimate (BOE)
- Cost Realism and Completeness
- Cost Reserves
- Comparison with T&C Estimates (Including Models/Analogies)



# Review

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## T&C: Definitions of the Findings

**Major Strength:** A facet of the response that is judged to be well above expectations and can substantially contribute to the ability to meet the proposed technical objectives and stay within resources available.

**Major Weakness:** A deficiency or set of deficiencies taken together that are judged to deleteriously affect the ability to meet the proposed technical objectives within the available resources.

**Minor Strength:** A strength that is substantial enough to be worthy of note and brought to the attention of proposers.

**Minor Weakness:** A weakness that is substantial enough to be worthy of note and brought to the attention of proposers.

**Note:** Minor findings can influence risk ratings.

Note: Normally, “as expected” findings should not be noted. However, findings that confirm analyses or comments to the Proposer or Selecting Official should be entered as “as expected”.



# Review

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## T&C Cost Review

- Proposed Mission Extensions cost is analyzed.
- Cost Realism is reported as a Cost Risk in one of the following 5 categories: 1) Low Risk, 2) Medium-Low Risk, 3) Medium Risk, 4) Medium-High Risk, and 5) High Risk.
- The Review of Cost Realism is based on the proposal provided cost data and the application of T&C Models and Analogies when appropriate.
- Cost threats, risks, and risk mitigation issues is inclusively identified and analyzed.
- The entire Review Panel participates in cost deliberations in developing a Cost Risk.
- A Cost Form to present the details of the cost analysis is developed.
- **The Cost Risk is integrated into the overall T&C Form Risk Rating.** All significant Cost Findings are included on the T&C Form.





# Review

## T&C Cost Risk Definitions

Cost Risk	Definition
LOW	The proposer's estimate agrees closely with the work, staffing, and schedule proposed, fits within the budget constraints and is verified by the T&C independent analysis.
MEDIUM-LOW	T&C review has identified one or more significant cost threats or weaknesses with regard to the proposer's estimate and/or resource management. The impact of identified threats or weaknesses should be manageable.
MEDIUM	T&C review has identified one or more significant cost threats or weaknesses with regard to the proposer's estimate and/or resource management. Cost impact of identified threats or weaknesses may be underestimated by the proposer, however these impacts should be manageable.
MEDIUM-HIGH	T&C review has identified one or more significant cost threats or weaknesses with regard to the proposer's estimate and/or resource management. Cost impact of identified threats or weaknesses may be underestimated by the proposer and these impacts may be challenging to manage within the funding constraints.
HIGH	T&C review has identified one or more significant cost threats or weaknesses in the proposer's estimate and/or resource management. The overall cost impact of identified threats or weaknesses exceeds the available resources. The threats and impacts may not be acknowledged by the proposer.



# Review Process

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## ESD Senior Review 2009 T&C Panel Participants

Role	Expertise
ESD Senior Review 2009 Chair	
T&C Review NASA Lead	
Principal Evaluator/Form Lead	Flight Systems
Principal Evaluator	Flight Systems
Principal Evaluator	Instruments
Principal Evaluator	Mission Operations
Principal Evaluator	Cost
Support Evaluator	Cost
Support Evaluator	Radiation
Support Evaluator	Radiation
Support Evaluator	LIDAR
Support Evaluator	Radar/Radiometers
Support Evaluator	MEMS/Electronics
Support Evaluator	Magnetics
Support Evaluator	Altimeter/Computing
Support & Continuity	Test Engineer



# Review Process

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## T&C Process Overview

### Individual Findings

- All subpanel members review the proposals and write an individual review before discussing findings with other members of the review team. They upload individual findings to the Remote Evaluation System (RES).

Fat Matrix Telecons; A fat matrix and a Draft T&C Form review telecon is held for each Proposal.

- T&C Form Lead guides the discussion of individual findings (on Fat Matrix) with the entire Review Team.
- T&C Form Lead guides the discussion of the Initial Draft T&C Form of previously discussed Proposals.

### Plenary Meeting

- T&C Form Lead guides a discussion to refine and finalize findings.
- Cost Risk is discussed and voted on.
- Votes are held to determine the Risk Ratings. Reviewers only vote on proposals that they have reviewed. Only reviewers that participate in the Plenary votes on the Ratings.



# Review Process

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## T&C Review Products

### T&C Form for each Proposal

Heading: Program Name, Proposal Title, Principal Investigator, Proposing Institution

### Rationale/Overall Evaluation

- Voting
- Risk Rating
- Rationale

### Strengths and Weaknesses

- Major Strengths
- Major Weaknesses
- Minor Strengths
- Minor Weaknesses

### Open Issues/Comments

- As Expected comments for Major Instruments and/or Cost.
  - Comments to Proposer
  - Comments to Selecting Official
  - Comments to the Senior Review Panel
- } Should be significant, not nits



# Review Process

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## T&C Review Products (continued)

### Cost Form for each Proposal

Heading: Program Name, Proposal Title, Principal Investigator, Proposing Institution

Cost Risk: Summary of Independent Assessment (sections below as applicable)

- Cost Risk Rating
- Cost Assessment Summary
- Cost Threats
- Risk Mitigation
- Issues/Questions
- Total Cost to NASA as Proposed
- Proposed Cost vs. Cost Review Estimates Tables
- Analogies and Comparisons Description
- ANALYSIS: Review of Cost Proposal
  - This is the review of the cost proposal itself for completeness, consistency, etc.



## General Observations

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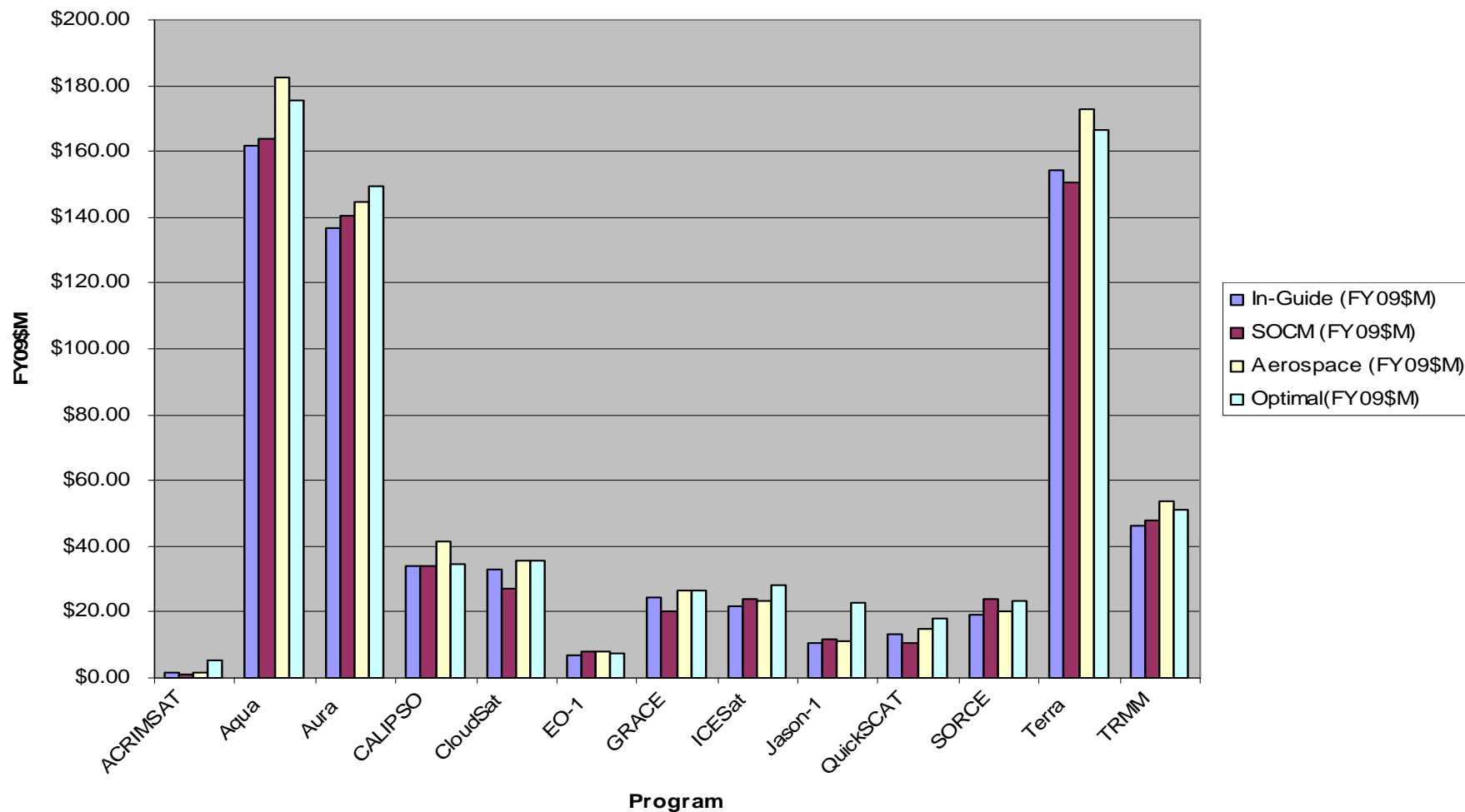
From observation of the T&C Review Team deliberations, seven issues had the most bearing on the Strengths and Weaknesses of the T&C review.

- 1.Redundancy - on the design, still operational
- 2.Time of operation (i.e., age)
- 3.Design – mechanical components?
- 4.Heritage – is there a predecessor system with long duration of flight operations.
- 5.Margin – power and propellant
- 6.Performance - failures to date e.g. due to Single Event Upsets (mechanical or electronic not link to redundancies)
- 7.Lack of information provided by the proposer



# ESD Missions Cost Comparison

Mission Cost Estimate Comparison





## Mission Extension Risk Ratings and Voting

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<b>Mission</b>	Low Risk	Medium Risk	High Risk	<b>Risk Rating</b>	Cost Risk
ICESat			5	High	Medium
QuickScat			5	High	Medium-High
Sorce		1	4	High	Medium
GRACE		3	2	Medium	Low
EO-1		4	1	Medium	Low
TRMM		5		Medium	Medium-Low
Terra		5		Medium	Medium-Low
Jason-1		5		Medium	Low
Aura		5		Medium	Medium-Low
Aqua		5		Medium	Medium-Low
CloudSat	5			Low	Low
CALIPSO	4			Low	Low
ACRIMSat	5			Low	Low





## ICESat Mission Extension Risk Rating and Rationale

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The ICESat mission extension is rated as **High Risk**. The T&C panel has identified 1 major strength and 1 major and 3 minor weaknesses. **All hardware on the fully redundant BCP 2000 spacecraft remains on the primary side. However, it is unlikely that the Geoscience Laser Altimetry System (GLAS) can survive 4 additional campaigns.** There is insufficient information in the report to assess ICESat mission team's concern about power margin and/or battery life during the proposed mission extension. The lack of information on total propellant, propellant usage and deorbit requirements prevents assessment of the propellant system. Budget and staffing reflected within "in-guideline" budget guidelines do not include preparation for mission termination and final calibration of data sets for transfer to users and ICESat-2 Mission. The panel has determined that, although the spacecraft is healthy, adequate laser operation for the proposed campaigns is unlikely. The cost risk is rated as Medium (refer to Cost Form).



## QuikScat Mission Extension Risk Rating and Rationale

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The QuikSCAT mission extension is rated as **High Risk**. The T&C panel has identified 1 minor strength and 1 major and 3 minor weaknesses. The mission's instrument, the SeaWinds Scatterometer (SWS), is a redundant, three block system that has been operating using the primary with no data quality degradation since launch, even though a bearing failure would render this redundancy irrelevant. However, **the project's estimate of the overall probability that the mission would fail during the proposed four (4) year extension was approximately 50%.** Both primary and back-up GPS receivers have had failures and the system has been operating on six of the twelve channels since March 2007. There has been a battery cell failure and the spare Common Pressure Vessel (CPV) was connected. With current minimum staff levels, no workarounds exist within the proposed "in-guideline" budget to allow operations to continue after 2012. The panel has determined that, considering the known failures and single-point failure vulnerabilities, the likelihood of necessary functionality for the spacecraft through the mission extension is remote. The proposers have failed to provide a plan for meeting the mission requirements to continue operations until FY 2013, within the "in-guideline" budget. The cost risk is rated as Medium-High (refer to Cost Form).



## SORCE Mission Extension Risk Rating and Rationale

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The SORCE mission extension is rated as **High Risk**. The T&C panel has identified 4 minor strengths and 1 major and 3 minor weaknesses. The Total Irradiance Monitor (TIM) operation is nominal and meets its performance requirements. Degradation of the two Solar Stellar Irradiance Comparison Experiment (SOLSTICE) instruments has been small through the first six years of the mission and the cross calibration has been effective. The XUV Photometer System (XPS) remains in very good health. Except for the single battery and reaction wheels, with the deactivation of reaction wheel #3, all systems are fully redundant and only the primary strings have been used. However, **the project, in combination with the hardware vendor, has determined that probability of premature failure for each remaining operational reaction wheel is 50%.** Multiple anomalies have resulted in up to 6%/yr degradation in the UV output of the Spectral Irradiance Monitor (SIM). The data and command systems have had multiple anomalies. The battery is experiencing a reduction in eclipse exit voltage. The proposed “in-guideline” budget guideline reflects a 22% budget cut rather than the expected 5%. The panel has determined that, because of the systematic fault in the reaction wheel design, and because of the undetermined repercussions of each successive failure, there is concern that the mission may not survive through the extended mission period. The cost risk is rated as Medium (refer to Cost Form).



## GRACE Mission Extension Risk Rating and Rationale

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The GRACE mission extension is rated as **Medium Risk**. The T&C panel has identified 1 major and 7 minor weaknesses. **GRACE-1 has been operating on the redundant Ultra Stable Oscillator (USO) for the past 7 years.** Launch-induced failures, infant mortality, and occasional interrupts and resets have impacted the operation of the instruments. The Instrument Control Unit (ICU) is on the redundant leg on each GRACE spacecraft. The GRACE mission requires that both GRACE satellites function properly. GRACE-2 suffered a cell failure in August 2007, leaving it with no battery redundancy. There have been failures of the Coarse Earth-Sun Sensor (CESS) head sensor thermistor triplets. University of Texas at Austin Center for Space Research (UTCSR) staffing and funding levels remain constant and do not include increased budget for increased staff efforts required in FY10 when the next generation of RL-05 data products are released. The Memorandum Of Understanding (MOU) between DLR and NASA for satellite operations has been extended to the end of 2009, with the expectation that “arrangements for extension of the MOU through 2015 will be in place before the end of 2009.” The panel has determined that, despite the known failures and single-point failure vulnerabilities, it is possible that both observatories can operate through the mission extension. The cost risk is rated as Low (refer to Cost Form).



## EO-1 Mission Extension Risk Rating and Rationale

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The EO-1 mission extension is rated as **Medium Risk**. The T&C panel has identified 1 minor strength and 1 major and 5 minor weaknesses. There is no indication of significant degradation or anomaly associated with the Advanced Land Imager (ALI) detectors. However, **minimal data on spacecraft systems and function are provided for an effectively single string spacecraft that has been in operation since November 2000**. The ALI solar calibrations were discontinued in 2007 due to failure of the solar mechanism. The Hyperion lamps have shown significant drifts and the Solid State Power Control (SSPC) that powers the Hyperion instrument appears to have experienced three (3) single-event latchup (SEL) events. The project presents inconsistent stances with respect to decommissioning of the spacecraft after the Mean Local Time (MLT) degrades to 9:45 AM, as well as when the degradation is expected to occur. The spacecraft operates in a high debris altitude, but there does not appear to be any mitigation for avoiding or becoming orbital debris. There is some question with regard to the validity of the project's product growth projection. The panel determined that not enough information was provided for assessing problems and potential problems that could affect the proposed mission extension (in-guideline terminating at 2012). Furthermore, the panel foresees the potential threat of a future funding request to extend the nominal mission, which is not covered by the optimal budget. The cost risk is rated as Low (refer to Cost Form).



## TRMM Mission Extension Risk Rating and Rationale

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The TRMM mission extension is rated as **Medium Risk**. The T&C panel has identified 1 minor strength and 4 minor weaknesses. The TRMM Microwave Imager (TMI) is functioning nominally to date and has heritage from the Special Sensor Microwave/Imager (SSM/I). However, one solar array drive has been parked and requires real time operator commanding during charging periods. No mention was made of the battery or reaction wheel status, which would be about 16 years old at the end of the extension. The duration over which TRMM will remain in orbit will be highly dependent on the amount of solar activity experienced over Solar Cycle 24. Staffing and budget reflected within the “in-guideline” budget are consistent with prior program history and sufficient to safely continue operations, but not sufficient to sustain planned Global Precipitation Measurement (GPM) algorithm development or sustained engineering support for GPM simulator instruments. The panel has determined that problems exist, but they can be addressed with good management and engineering solutions. The cost risk is rated as Medium-Low (refer to Cost Form).



## Terra Mission Extension Risk Rating and Rationale

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The Terra mission extension is rated as **Medium Risk**. The T&C panel has identified 5 minor strengths and 7 minor weaknesses. Multi-angle Imaging SpectroRadiometer (MISR) appears to be in robust health with full redundancy. Even though one solar array shunt has failed, the array continues to produce 1 kW in excess power even with a -20 degree offset. With the exception of the Direct Access System (DAS) Modulator (DASM), all components of the Terra Communications Subsystem retain their redundancy. The Attitude Determination and Control System (ADCS) appears to be in good condition with redundancy still remaining in all areas. The spacecraft will have about 35kg of fuel margin at the end of the mission extension. However, the Advanced Spaceborne Thermal Emission and Reflection (ASTER) radiometer has lost its 6 Short Wave Infrared (SWIR) channels, and the 3 Visible Near Infrared (VNIR) channels are degrading. The Moderate Resolution Imaging Spectroradiometer (MODIS) has lost full redundancy as it uses A-side electronics and a B-side formatter, and its permanently open solar diffuser door is a major concern for contamination. In 2001, Measurement Of Pollution In The Troposphere (MOPITT) lost four of its eight channels due to the failure of one of its coolers. Other than the pressure issue there was no discussion of battery temperature ranges, depth of discharge issues, or predicted voltages. The Solid State Recorder (SSR) has lost about 12.1% of storage capacity due to Single Event Upsets (SEUs). The unusually high number of SEUs/electrical anomalies adds to operational complexity. Staffing and budget is sufficient to safely fly mission but not sufficient within the “in-guideline” to bring ground systems compliant with NPR 2810-1A. The panel has determined that problems exist, but they can be addressed with good management and engineering solutions. The cost risk is rated as Medium-Low (refer to Cost Form).





## Jason-1 Mission Extension Risk Rating and Rationale

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The Jason-1 mission extension is rated as **Medium Risk**. The T&C panel has identified 2 minor strengths and 1 major and 3 minor weaknesses. The overall performance of the Jason-1 Microwave Radiometer (JMR) continues to be excellent and current trends indicate that instrument health should remain nominal for the next five years. Poseidon-2 should continue to meet science requirements for at least the next five years; a similarly designed altimeter operated nominally for the entire 13-year duration of the TOPEX/Poseidon mission. However, **multiple failures have effectively left Jason-1 with a degraded single string spacecraft that has been in operation since December 2001**. DORIS is now a single-string instrument. Turbo Rogue Space Receiver (TRSR) GPS system primary has experienced degradation, while the backup has failed completely. The solar array drive motors will exceed their qualified cycle life at the end of the proposed optimal mission. The panel has determined that there are a number of problems, however the mission is only expected to operate for another year in the in-guideline budget. The risks are higher for the optimal budget scenario. The cost risk is rated as Low (refer to Cost Form).





## Aura Mission Extension Risk Rating and Rationale

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The Aura mission extension is rated as **Medium Risk**. The T&C panel has identified 2 minor strengths and 1 major and 4 minor weaknesses. Guidance Navigation and Control (GN&C), Communication, and thermal systems appear to be healthy and with no failures that threaten mission extension. At the end of the mission extension Aura should have more than 100kg of propellant left; de-orbit will cost about 30kg leaving 70kg of margin. However, **the High Resolution Dynamics Limb Sounder (HIRDLS) is not currently functioning because of a failure of its chopper motor, and the mitigation scheme, even if successful, may contaminate other parts and damage optical components.** Band 13 in the Microwave Limb Sounder (MLS) is not operational, and four others are experiencing different anomalies that may lead to total failure of these channels. The increases in the Tropospheric Emissions Spectrometer/Interferometer Control Subsystem (TES/ICS) motor current over time is a critical issue and may affect data quantity and quality during the extension period. Neither the benefit associated with Autonomous Operations (Auto-Ops) of the Solid State Recorder (SSR), nor the possible data loss due to a plan to implement “no overlap data in the SSR playback” is provided. The staffing and budget reflected within the “in-guideline” budget guideline is sufficient to safely fly the mission but not sufficient to bring the ground systems compliant with NPR 2810-1A. The panel feels that minimal problems exist, however they can be overcome with management, good engineering, and trades. The cost risk is rated as Medium-Low (refer to Cost Form).



## Aqua Mission Extension Risk Rating and Rationale

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The Aqua mission extension is rated as **Medium Risk**. The T&C panel has identified 1 major and 2 minor strengths and 4 minor weaknesses. **The Aqua spacecraft appears to be in excellent health and is expected to fully operate during the proposed mission extension.** The Moderate Resolution Imaging Spectroradiometer (MODIS) has had no issues or problems, has been fully operational, and has a high probability to remain functional through 2013. The Advanced Microwave Scanning Radiometer for EOS (AMSR-E) has performed well since Aqua launch in May 2002 and is expected to perform through the mission extension, even though there have been some torque excursions over the past two years. However, the Advanced Microwave Sounding Unit (AMSU) has lost or degraded 3 of its 15 channels and the Project's anticipation of further degradation has led to development of an Atmospheric Infrared Sounder (AIRS)-only retrieval algorithm. Autonomous Operations (Auto-Ops) of the Solid State Recorder, while providing an unquantified cost savings, is predicted to result in a data loss of "1-3%, based on ground station performance over the last 12 months." Several operator error anomalies were noted during this report and there was no clear indication that the root causes of those operator errors have been addressed to preclude recurrence. The staffing and budget reflected within the "in-guideline" budget guideline is sufficient to safely fly the mission but not sufficient to bring the ground systems compliant with NPR 2810-1A. The panel feels that minimal problems exist, however they can be overcome with management, good engineering, and trades. The cost risk is rated as Medium-Low (refer to Cost Form).



## CloudSat Mission Extension Risk Rating and Rationale

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The CloudSat mission extension is rated as **Low Risk**. The T&C panel has identified 3 minor strengths and 1 minor weakness. CloudSat's instrument, the Cloud Profiling Radar (CPR), has been operating above its minimum sensitivity requirement since launch; its critical component, the high power amplifier, is doubly redundant which allows for continued operation if the primary becomes out of specification for sensitivity and/or output power. Other than the battery, key elements on the spacecraft are performing nominally, only using a fraction of their design life (and expected to be functional beyond the design life based on other flight hardware). CloudSat appears to have sufficient propellant to extend the mission and still be able to deorbit. However, for the proposed extended mission through 2013, the battery will be the equivalent of an 11-year-old battery, as the CloudSat's battery was activated approximately five-years before launch. The panel is confident that even though a minor problem exists, it is manageable and the mission can continue through the extension period. The cost risk is rated as Low (refer to Cost Form).



## CALIPSO Mission Extension Risk Rating and Rationale

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The CALIPSO mission extension is rated as **Low Risk**. The T&C panel has identified 1 major and 2 minor strengths and 2 minor weaknesses. **CALIPSO maintains all of its original subsystem redundancies.** The Wide Field Camera (WFC) has not demonstrated any anomalies and appears to be in excellent health. If CALIPSO continues to use propellant at the same rate, it should have twice the propellant needed for the mission extension. However, the primary laser in CALIOP (Cloud-Aerosol Lidar with Orthogonal Polarization), which is the mission critical instrument, failed after three years and the instrument is using the backup laser. Although the payload controller is, for the most part, healthy the temperature rise in the low voltage power supply is a concern. The panel is confident that the mission can continue to operate through the mission extension period. The cost risk is rated as Low (refer to Cost Form).



## ACRIMSAT Mission Extension Risk Rating and Rationale

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The ACRIMSAT mission extension is rated as **Low Risk**. The T&C panel has identified 1 major and 3 minor strengths. **The ACRIM3 instrument appears to be in excellent health and is expected to fully operate during the proposed mission extension period.** The spacecraft appears to be in excellent health. The primary ground station has operated 99.8% error free throughout the nine-year mission, and is backed up by three NASA ground stations, of which a minimum of two communicate with the spacecraft for one orbit of commanding and data download each month. The mission proposes that they have been able to operate ACRIMSAT at annual cost savings of 30% since FY 08. The panel is confident the mission can operate through two year (in-guideline) or four year (optimal) mission extensions. The cost risk is rated as Low (refer to Cost Form).